Attorney Docket No.: C36305

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COPY

PATENTS

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)

International Application No.: PCT/SE98/00613

International Filing Date: 3 April 1998

Priority Date Claimed: 4 April 1997

Title of Invention: METHOD AND APPARATUS FOR FRICTION STIR WELDING

Applicant(s) for DO/EO/US:

Applicant herewith submits to the United States Designed/Elected Office (DO/EO/US) the following items under 35 U.S.C. 371:

1. ✓ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.

2. ___ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.

3. ✓ This express request to immediately begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).

4. ___ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. ✓ A copy of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ✓ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ___ has been transmitted by the International Bureau.
   c. ___ is not required, as the application was filed in the United States Receiving Office(RO/US).

6. ___ A translation of the International Application into English.

7. ✓ Amendments to the claims of the International Application under PCT Article 19
   a. ___ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ✓ have been transmitted by the International Bureau.
   c. ___ have not been made; however, the time limit for making such amendments has **NOT** expired.
   d. ___ have not been made and will not be made.

8. ___ A translation of the amendments to the claims under PCT Article 19(35 U.S.C. 371(c)(3)).

9. ✓ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4))
   a. ___ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ___ has been transmitted by the International Bureau.
   c. ✓ will follow.

10. ___ A translation of the Annexes to the International Preliminary Examination Report under PCT Article 36 (35. U.S.C. 371(c)(5)).

11. ✓ Copy of the ✓ International Preliminary Examination Report and/or the ✓ International Search Report.

12. ✓ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

13. ✓ An Assignment document for recording with a separate cover sheet in compliance with 37 CFR 3.28 and 3.31
   a. ___ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ___ has been transmitted by the International Bureau.
   c. ✓ will follow.

14. ✓ A **FIRST** preliminary amendment.
   A **SECOND** or **SUBSEQUENT** preliminary amendment.

15. ___ A substitute specification.

16. ___ A change of power of attorney and/or address letter.

17. __ Verified Small Entity Declaration.
    a. __ is transmitted herewith (required only if not transmitted by the International Bureau).
    b. __ has been transmitted by the International Bureau.
    c. __ will follow.

18. ✓ Other items of information: Schedule A of Inventors

19. ✓ (1) sheet of drawing is enclosed. (figure 1)

20. ✓ The U.S. National Fee (35 U.S.C. 371(c)(1)) and other fees as follows:

BASIC NATIONAL FEE (37 CFR 1.492 (a)(1)-(5)): __ Search Report has been prepared by the EPO or JPO = $840 __ International preliminary examination fee paid to USPTO (37 CFR 1.482) = $700 __ No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) = $760 ✓ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO = $970 __ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) = $96	$ 970.00
Surcharge of **$130** for furnishing the oath or declaration later than the __ **20** ✓ **30** months from the earliest claimed priority date (37 CFR 1.492(e)).	TOTAL FEE FOR LATE FILING OF OATH/DECLARATION $
NUMBER OF INDEPENDENT CLAIMS CLAIMS OVER 3 RATE 2 - 3 = 0 X $78=	TOTAL FEES FOR INDEPENDENT CLAIMS OVER 3 $
MULTIPLE DEPENDENT CLAIMS(S) PRESENT RATE $260 PER APPLN.	FEE FOR MULTIPLE DEPENDENT CLAIM(S) $
TOTAL NUMBER OF CLAIMS CLAIMS OVER 20 RATE 12 - 20 = 0 X $18 =	TOTAL FEES FOR CLAIMS OVER 20 $ 0
TOTAL OF ABOVE CALCULATIONS	$
Reduction by 1/2 for filing by small entity	$
SUBTOTAL	$ 970.00
ASSIGNMENT RECORDAL SHEET	$
Processing fee of **$130** for furnishing the English translation later than the __ **20** ✓ **30** months from the earliest claimed priority date (37 CFR 1.492(f)).	$ 0
TOTAL FEES ENCLOSED	$ 970.00

a. ✓ A check in the amount of $ 970.00 to cover the above fees is enclosed.
b. __ Please charge my Deposit Account No. 04-2219 in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.
c. ✓ The Commissioner is hereby authorized to charge any additional fees which may be required, including request for extension and payment of extension fees due, when this is not explicitly requested by applicants, with a view toward avoidance of abandonment, to Deposit Account No. 04-2219, referencing our docket # C36305. Any over-payment should be credited to this account.

Please direct all communications in connection with this application to the undersigned at:

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EXPRESS MAIL CERTIFICATION

"Express" Mail label number: EL439221397
Date of Deposit: September 28, 1999

I hereby certify that this transmittal letter and the papers and fees identified in this transmittal letter as being transmitted herewith are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 on the date indicated at (A) above and are addressed to the Commissioner of Patents & Trademarks, Washington, D.C. 20231

Eileen M. Martin

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of	)
	)
Applicant: KNIPSTROM, Karl-Erik	)
	)
Serial No.: New U.S. Application	)
PCT Application No.: PCT/EP98/00613	)
Filed: Herewith	)

For: METHOD AND APPARATUS FOR FRICTION STIR WELDING

Attorney Docket No. C 36305

PRELIMINARY AMENDMENT

Hon. Commissioner of
Patents and Trademarks
Box PCT
Washington, D.C. 20231

September 28, 1999

Sir:

Please amend the newly submitted patent application described above as follows:

In the Claims:

Please amend the claims as follows:

In claim 1, line 8, delete "characterised in that" and insert --wherein--.

In claim 2, lines 1 and 2, delete "characterised by" and insert --wherein--.

In claim 3, lines 1 and 2, delete "claim 1 or 2 , characterised in that" and insert --claim 1, wherein--.

In claim 4, lines 1 and 2, delete "in any one of the preceding claims, characterised in that" and insert --claim 3, wherein--.

In claim 5, lines 1 and 2, delete "characterised in that" and insert --wherein--.

In claim 6, lines 1 and 2, delete "characterised in that" and insert --wherein--.

In claim 7, lines 1 and 2, delete "claims 4, 5, or 6, characterised in that" and insert --claim 6, wherein--.

In claim 8, line 8, delete "characterised by" and insert--wherein--

In claim 9, lines 1 and 2, delete "characterised in that" and insert --wherein--.

In claim 10, lines 1 and 2, delete "claim 8 or 9, characterised by" and insert --claim 9, wherein--.

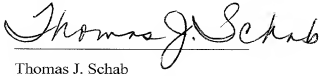
In claim 11, lines 1 and 2, delete "characterised in that" and insert --wherein--.

In claim 12, lines 1 and 2, delete "characterised in that" and insert --wherein--.

REMARKS

The foregoing amendments are primarily for the purpose of eliminating multiple dependencies, and placing the claims in proper form.

Respectfully submitted,



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TJS/em

METHOD AND APPARATUS FOR FRICTION STIR WELDING

The present invention relates to a friction stir welding method according to which the workpieces to be welded are positioned on a work-table and by means of clamping means clamped to one another and/or to the work-table and according to which a rotating welding means is arranged to move along a joint between the workpieces while being pressed against said workpieces during the welding.

The present invention likewise relates to an apparatus for friction stir welding, comprising a work-table supporting the workpieces to be welded, at least one clamping means for clamping the workpieces to one another and/or to the work-table, and a welding means adapted to be advanced along a joint between the work-pieces while being pressed against said workpieces during the welding.

The definition friction stir welding designates a welding method according to which the workpieces to be joined together are plasticized along their joint line by supply of frictional heat from a rotating welding probe, said probe being moved along the joint between the work-pieces while at the same time being pressed against the work-pieces. As described in WO93/10935 and W095/26254 the welding probe should be manufactured from a material that is harder than that of the workpieces, and during the welding operation the workpieces should be securely fixed relative to one another and to the work-table. In this respect this technique differs from that of conventional friction welding according to which the frictional heat is generated by the relative motion of the workpieces as they are being pressed together, i.e. the frictional heat is generated only by the two components to be joined together. This friction stir welding technique according to the above-mentioned publications

is used for the welding of different materials, such as plastics, metals, etcetera in various fields of application, for example to join workpieces together, to repair cracks in a workpiece, and so on. The design of the welding probe is conditioned e.g. by the material to be welded and by the intended application.

In gas metal arc welding and particularly in submerged arc welding when the molten pools generally are of considerable dimensions, a backing means is often used, i.e. a backing bar which is pressed against the back of the joint during the welding operation in order to support the edges of the joint and to prevent the molten pool from escaping as the complete weld penetra-tion stage is reached. In constructing the backing means thermal considerations are to a large extent decisive in the choice of the backing means material, particularly in the case of welding of aluminium. The cooling effect on the joint from the backing means must not be too powerful.

Similarly, backing means are likewise used in complete penetrating welding in connection with friction stir welding. In this case, the backing means serves as a mechanical support and shapes the lower face of the joint. Also in this case the backing means may be formed with a thermal barrier against a subjacent backing bar in order better to take advantage of the friction heat generated in the welding process.

One of the problems encountered in friction stir welding of hard-to-weld materials, such as aluminium alloyed with magnesium, with lithium or with copper, is that the forces deployed during the welding operation are of such a magnitude as to cause the welding probe to break after a comparatively short period of welding, as a result of fatigue. This is true particularly of workpieces that have a thickness exceeding 5 mm.

Another problem is the generation of short but deep cracks in the surface of the backing means, particularly

in the transverse direction of the latter, due to thermal fatigue. Because the joint, owing to the plasticisation thereof during the welding operation, will adopt the appearance of the backing means surface, these cracks will manifest themselves as protrusions on the lower face of the joint, and as a result the joint will be unacceptable.

A further problem is that the frictional heat generated in hard-to-weld materials may be insufficient, and that consequently complete weld penetration is not achieved, or that lack of fusion will occur.

One object of the present invention therefore is to provide a method and an apparatus for friction stir welding by means of which it becomes possible to substantially prolong the serviceable life of said welding probe. It is likewise desirable to simultaneously increase the quality of the formed joint, primarily by securing safe weld penetration and complete fusion vis à vis the base material, and in addition thereto increase productivity.

This object is achieved in accordance with the present invention by means of a friction stir welding method of the kind defined in the introduction, which method is characterised in that additional heat is supplied to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means, the start of the welding operation proper considered to be the instant when the welding probe is lowered into the joint.

In order to achieve said object, the present invention also provides an apparatus of the kind outlined in the introduction for friction stir welding, which apparatus is characterised by a heating means for supply of additional heat to the joint prior to and/or during the welding operation, in excess of the frictional heat

generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means.

Due to the supply of additional heat to the joint between the workpieces in excess of the frictional heat generated through the rotation of the welding means and any other heat that may be supplied to the joint by the welding means in any other manner, the serviceable life of the welding probe is prolonged considerably. In cases when the joint is backed up by means of a subjacent backing means, cracking of the latter is also prevented, if heat is supplied to the joint by way of the backing means. The difference is pronounced and is a prerequisite for the welding of for instance several aluminium alloys with acceptable economy. In addition, higher welding quality is obtained because of improved penetration and safer bonding against the base material, and it also becomes possible to increase the welding speed with consequential higher productivity.

Advantageous modified varieties of this method and this apparatus will be defined in the dependent claims.

The invention will be described in the following in closer detail with reference to the accompanying drawing figure illustrating one embodiment of the apparatus in accordance with the present invention.

The apparatus 1 shown in the drawing figure is intended for welding together two workpieces 2, 3, the latter being e.g. extruded aluminium profile sections.

During the welding operation, the workpieces 2, 3 are secured to the work-table 7 by clamping means 5 and 6, respectively. The clamping means 5 and 6, respectively, may consist of a compression cylinder. The present work-table is a horizontal machine table 7a to which a backing means 7b is stationarily secured by means of a backing bar 7d in the shape of an I-beam and which is supported by a stationary, rigid frame 7c. The backing means 7b is formed with a groove 60 extending in the

longitudinal direction of the support, said groove having received therein a heating coil in the form of a heating cable 70.

The joint between the workpieces 2, 3 is placed in alignment with the centre line of the backing means. The backing means backs up also the edges of the joint and prevents the plasticized material from flowing away at the attainment of complete weld penetration.

Welding is performed by means of a welding means in the form of a welding probe 12 and a rotating spindle 13. The welding probe consists of a cylindrical body 12a having attached thereto a cylindrical pin 12b the circumference of which is smaller than that of the probe body. Owing to this arrangement, the lower part of the cylindrical body will project beyond the upper part of the pin. In the following, the lower part of the body will be referred to as the shoulder of the body, and as appears from the drawing figure the shoulder abuts against the upper faces of the workpieces 2, 3 in the normal position of the welding probe. The welding probe body and pin could be configured for example in conformity with any one of the embodiments shown in WO93/10935 or in WO95/26254. The upper part of the body 12a is connected to the rotating spindle 13 which is driven by a drive unit, not shown, such as a drive motor.

The workpieces 2, 3 are first secured in the apparatus 1 by means of the clamping means 5, 6, care being taken that the air gap, i.e. the joint, between the facing end edges of the profile sections does not exceed the dimensions that are liable to cause a deficient weld to form. As appears from the drawing figure, the gap is placed in alignment with the centre line c of the backing means 7b. The backing means is then pre-heated by means of the built-in heating cable 70, until the temperature of the backing means is in the range of 150-250°C. This temperature range is detected by traditional means, for instance by a temperature sensor, not shown. Following

the pre-heating of the backing means, and thus of the joint, the welding operation is initiated by the welding probe being made to rotate at a certain speed while at the same time being advanced along the gap at a predetermined speed. As described initially, the end edges of the profile sections will become plasticized by the frictional heat generated during this process.

The resulting welded joint, when solidified, is a homogeneous, high-strength joint.

It should be appreciated that the invention is not limited to the above embodiments but could be modified in a number of different ways within the scope of the appended claims. For example the backing means 7b could be heated by a heating fluid supplied to the groove 60 or by indirect supply of electricity instead of by means of a heating cable 70 built into the groove. Instead of heating the joint via the backing means, the joint could be heated by a heating element, such as a gas burner positioned underneath the joint or in contact with the sides of the joint. Induction heating is another possible method of supplying the additional heat. The apparatus could of course be used for welding together workpieces of other metals or metal alloys than aluminium, such as e.g. titanium or steel. When the apparatus is used to weld together titanium or steel workpieces the backing means should be heated to temperatures in the range of 500-1000°C.

CLAIMS

1. A friction stir welding method according to which the workpieces (2,3) to be welded are positioned on a work-table (7) and by means of clamping means (5,6) clamped to one another and/or to the work-table and according to which a rotating welding means (12, 13) is arranged to move along a joint between the workpieces while being pressed against said workpieces during the welding, c h a r a c t e r i s e d in that additional heat is supplied to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means (12, 13) and, in excess, of any other heat that may be supplied to the joint in any other manner by the welding means (12, 13).

2. A method as claimed in claim 1, c h a r a c t e r i s e d by pre-heating the joint to a maximum of 250°C below the fusion temperature of the material of the joint.

3. A method as claimed in claim 1 or 2, c h a r a c t e r i s e d in that the joint is heated by a heating element positioned underneath the joint.

4. A method as claimed in any one of the preceding claims, c h a r a c t e r i s e d in that the joint is supported by a subjacent backing means (7b) which is pre-heated to a temperature in excess of 100°C.

5. A method as claimed in claim 4, c h a r a c t e r i s e d in that the backing means is heated to a temperature in the range of 150-250°C.

6. A method as claimed in claim 4, c h a r a c t e r i s e d in that the backing means is heated to a temperature in the range of 500-1000°C.

7. A method as claimed in claims 4, 5 or 6, c h a r a c t e r i s e d in that the backing means (7b) is heated by a heating coil (70) built into backing means.

8. An apparatus (1) for friction stir welding, comprising a work-table (7) supporting the workpieces (2,3) to be welded, at least one clamping means (5,6) for clamping the workpieces to one another and/or to the work-table, and a welding means (12, 13) adapted to be advanced along a joint between the workpieces while being pressed against said workpieces during the welding, c h a r a c t e r i s e d by a heating element (70) for supply of additional heat to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means (12, 13) and of any other heat that may be supplied to the joint in any other manner by the welding means (12, 13).

9. An apparatus as claimed in claim 8, c h a r a c t e r i s e d in that it comprises a heating element positioned underneath the joint.

10. An apparatus as claimed in claim 8 or 9, c h a r a c t e r i s e d by a backing means (7b) positioned underneath the joint.

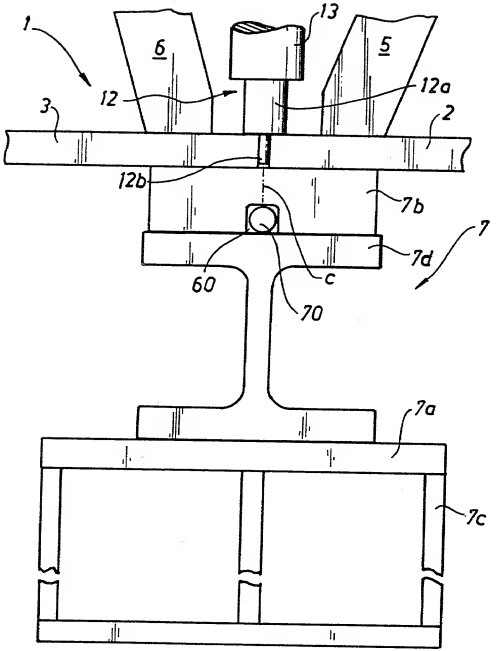
11. An apparatus as claimed in claim 10, c h a r a t e r i s e d in that the backing means (7b) is adapted to be heated by the heating element (70).

12. An apparatus as claimed in claim 11, c h a r a c t e r i s e d in that the heating element is a heating coil (70) built into the backing means (7b).

09/402185
420 Rec'd PCT/PTO 28 SEP 1999

ABSTRACT

The invention concerns a friction stir welding method according to which the workpieces (2, 3) to be welded are positioned on a worktable (7) and by means of clamping means (5, 6) clamped to one another and/or to the work-table during the welding. A rotating welding means (12, 13) is arranged to move along a joint between the work pieces while being pressed against said workpieces during the welding. Additional heat is supplied to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means. the invention likewise concerns an apparatus for friction stir welding, comprising a heat element (70) for supply of additional heat to the joint prior to and/or during the welding operation, in excess of the frictional heat generated in the joint from the rotation of the welding means and of any other heat that may be supplied to the joint in any other manner by the welding means.



DECLARATION O. NVENTORSHIP AND POWER OF TTORNEY FOR UNITED STATES PATENT OR DESIGN APPLICATION

Attorney Docket No. C36305.....

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD AND APPARATUS FOR FRICTION STIR WELDING .....,
the specification of which

(check one)
{ } is attached hereto.
{ } was previously filed. U.S. serial number not yet available to applicant. A copy of the specification as filed is attached for identification purposes.
{ } was filed on . . . . . Attorney Docket No.....
{✓ } was filed on . September 28, 1999. under Application Serial No. 09/402,185.....

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Office all information which is material to Patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 USC § 119 or 35 USC § 172 of any foreign application(s) listed below.

Prior Foreign Application(s):

APPLICATION NUMBER	COUNTRY	FILING DATE (Day/Month/Year)
9701265-2	Sweden	4 April 1997 .....
.....		
.....		

I hereby claim the benefit under 35 USC § 120 of any United States application (s) listed below, and any prior filed International application under 35 USC § 365 listed below, and insofar as the subject matter of each of the claims of this application is not disclosed in the prior application, I acknowledge the duty to disclose to the Office information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the filing date of this application

APPLICATION NUMBER	FILING DATE (Day/Month/Year)	STATUS (Patented, Pending, Abandoned)
PCT/SE98/00613	3 April 1998	pending.....
.....		
.....		

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: GEORGE F. DVORAK (17656), KEITH H. ORUM (33985), THOMAS J. SCHAB (35908), SUSAN M. KEATING (41887).

Address all telephone calls and correspondence to:

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Chicago, Illinois 60604-3606
Telephone No. 312 922 6262
Fax No. 312 922 7747

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 USC 1001, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Full name of sole or first inventor: KNIPSTRÖM, Karl-Erik

Inventor's signature: K-E Knipström Date: 9 December 1999

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Inventor's signature: Anders Malm Date: 9 December 1999

Residence (City & Country): Laxå, SWEDEN SW Citizenship: Swedish

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Full name of third joint inventor, if any

Inventor's signature: Date:

Residence (City & Country Citizenship:

Post Office Address:

Full name of fourth joint inventor, if any

Inventor's signature: Date:

Residence (City & Country): Citizenship

Post Office Address

Full name of fifth joint inventor, if any:

Inventor's signature: Date:

Residence (City & Country): Citizenship:

Post Office Address:

Full name of sixth joint inventor, if any:

Inventor's signature: Date:

Residence (City & Country): Citizenship:

Post Office Address:

Full name of seventh joint inventor, if any:

Inventor's signature: Date:

Residence (City & Country): Citizenship:

Post Office Address: